



Cloud Optical Depths at Night: Going Beyond the Infrared Blackbody Limits?

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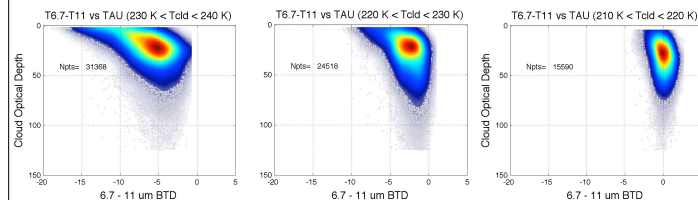
<http://www-angler.larc.nasa.gov/satimage/products.html>

Introduction

During daytime, cloud properties such as cloud optical depth (OD), effective particle size R_e , and water path (WP) can be derived for a wide range of cloud thicknesses because the reflectance at visible wavelengths is sensitive to changes in optical depth from OD < 1 to OD > 100. At night, information from solar channels is unavailable, so retrievals of the cloud properties are typically limited to clouds having OD < 6, because the cloud is essentially a blackbody at greater optical depths, at least for the window channel wavelengths (10-12 μm) typically used for retrievals from satellite imagers. This limitation constrains the monitoring of cloud properties over the full diurnal cycle and leaves a gap in the ability to characterize clouds both at meteorological and climate scales. This paper examines the potential of using additional channels available on some current imagers and on the GOES-R ABI to extend the range of ice cloud optical depths that can be determined from radiances measured at night. Wavelengths, 3.9, 6.7, 7.1, 10.8, and 12 μm , are considered here.

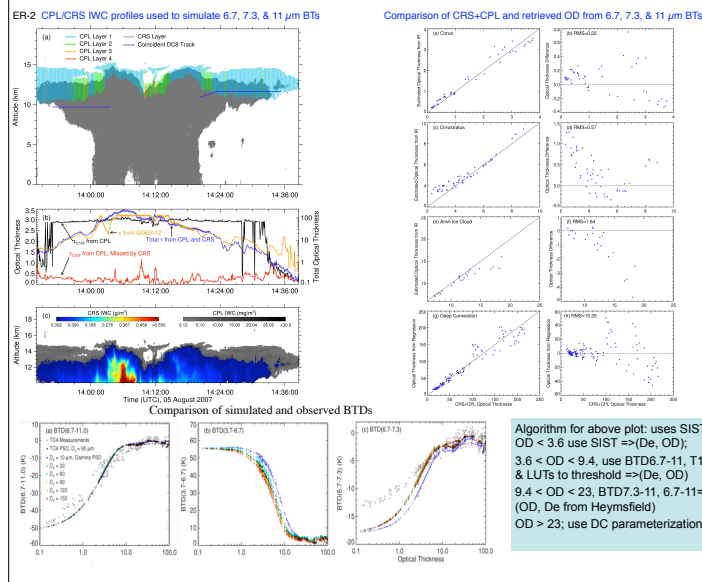
Correlation of BT6.7-11 and OD

Matched BT6.7-11 and OD data from several months of GOES-12 data, like the images to the right, were amassed and plotted as a function of OD. The apparent correlation tends to increase as Tcld increases, with possible usable information up to OD = 20 or so. Yet, even for low Tcld values, there may be some independent information. Note that the data were not screened for ML clouds that cause some of the spread or decorrelation. These observations represent a starting point for this study.



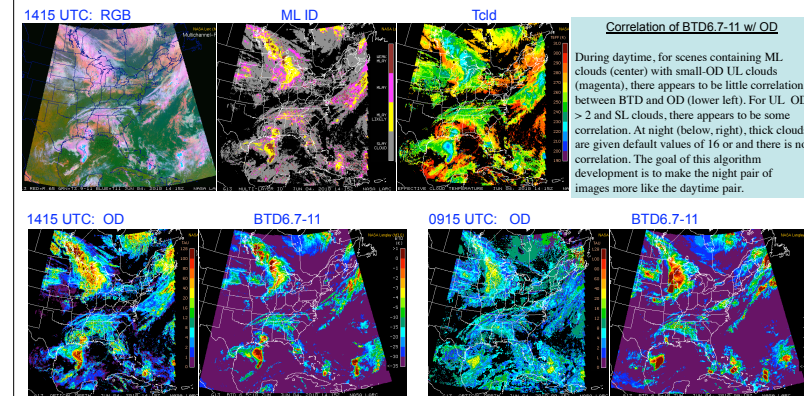
Case Study, TC4

A thick deep convective anvil observed by the ER-2 Cloud Physics Lidar (CPL) and Cloud Radar System (CRS) during TC4 on 5 August 2007 was used to simulate radiances observed from Aqua MODIS at 3.7, 6.7, 7.3, and 10.8 μm . Nearest balloon sounding and average Heymsfield variation of ice particle size with temperature used with CRS IWC profiles in radiative transfer model. Observations match well for OD > 3 (bottom). Results form basis for initial algorithm.



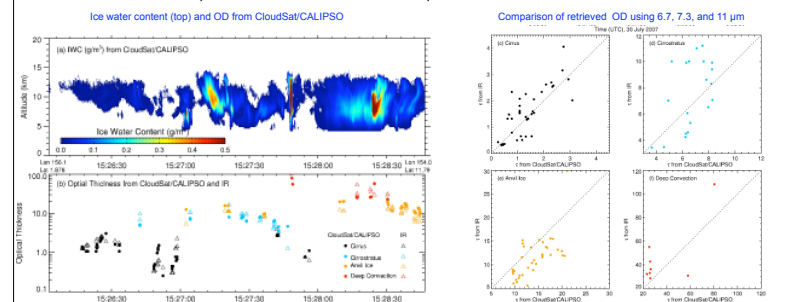
Observations & Retrievals, Example of Current Methods

The examples below are from data taken from GOES-13, 4 June 2010 during daytime (1415 UTC) and nighttime (0915 UTC). The optical depths are derived using single layer (SL) cloud assumption with VISST (daytime) and SIST (nighttime). Because of the blackbody limitations, clouds with OD < 6 are given default values at night. Cloud effective temperature (Tcld) is the effective radiating temperature of the cloud. The multilayer (ML) cloud identification uses the VISST OD and retrievals based on 10.8 and 13.3 μm channels (Chang et al., 2010). Magenta indicates upper layer (UL) clouds with optical path lengths equivalent to OD < 2; yellow to OD < 6; brown > 6.



Example using CloudSat/CALIPSO data

This method can be tested using CloudSat and CALIPSO data during day and night. Example here uses data taken over ocean using Aqua MODIS data. The correlations reasonable for OD < 23, not so good for thicker clouds, though little data involved. Much additional data is needed to refine this method. 3.7 μm data can also be used instead of 7.3 μm .



Summary

- The concept of a new algorithm to estimate optical depths in ice clouds observed only with infrared spectra has been demonstrated. Preliminary results indicate some skill for obtaining thick cloud optical depths more accurately than using defaults. Will be valuable for GOES-R ABI and older GOES.
- Much additional research is needed
 - reducing calculation times, perhaps, through parameterizations
 - potential to use empirical results
 - possible use in multilayer detection